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Forecasting Research Division
Technical Report No.94

A comparison of the image obliquity of geostationary satellites and overlapping swaths from polar orbiting satellites at middle and high latitudes

by

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28th April 1994

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1 Introduction

At very high latitudes, overlapping image swaths from polar orbiting satellites offer a better combined obliquity than images from geostationary satellites, while at low latitudes the reverse is true. 'Combined obliquity' refers to the obliquities of two consecutive overpasses of a single polar orbiter for a fixed point on the earth's surface. The following work was undertaken to determine at which latitude the obliquities of images from the two types of satellite are equivalent. With this established, it can be determined which type of satellite image will give a better obliquity when deriving satellite products (particularly cloud-motion wind vectors) at a particular latitude.

Note that other factors will affect the accuracy of cloud-motion wind vectors, specifically the spatial and temporal resolutions of the two types of data. Thus, equally accurate winds are not expected at the latitude where the obliquities are equivalent; however, determining the latitude at which equally accurate winds can be derived is a much more involved question than the present work.

2 Method

The obliquity of a satellite image at a particular latitude (α in Figure 1) was calculated for a grid of points on the earth's surface, between latitudes 30° and 75° with a 5° spacing, and between longitudes $-20°$ and 20° with a 2° spacing.

For a geostationary satellite at 0° longitude, at a height of 35785.845 km above the earth's surface, a single value of the α angle was determined for each grid point.

For a polar orbiting satellite at a height of 825 km above the ground, two values of α were calculated for a grid point, i.e. one each for two successive polar orbits. With an orbit time of 101 minutes, the two orbits were 25.25° longitude apart. Thus two orbits were chosen which were roughly either side of 0° longitude, and for each grid point, if it was in the field of view of both orbits, an angle was calculated for each orbit, α_1 and α_2. (In all calculations, the radius of the earth was taken as 6378.155 km.)

For each latitude value, the range of values of α_1 and α_2 were plotted – values for the polar orbiter were plotted as '×'s, and values for the geostationary satellite were plotted as 'o's (since only one angle was calculated for a grid point from the geostationary satellite, $\alpha_1 = \alpha_2$ always). At the latitude where the points coincided (i.e. where $(\alpha_1 + \alpha_2)_{\text{polar}} \approx 2\alpha_{\text{geo}}$), the image obliquities of geostationary and polar orbiting satellites would be equivalent.

3 Results and Conclusions

As can evidently be seen from the results (Figure 2(a)-(d)), the points for the two satellites coincide at around latitude 45°; at this latitude, the α angles are roughly equal, and so the image obliquities will be about the same. At lower latitudes (say 35°), the α angles for the geostationary satellite are smaller, and so this has a better obliquity than the polar orbiting satellite. At higher latitudes (65°), the α angles for the polar orbiter are smaller, so this has the better obliquity.

It is noted that for current NOAA series polar orbiters, the satellite viewing angle (denoted by γ in Figure 1) is constrained to be less than 55°. As a consequence, the α angles are constrained to be less than 67.7°. These limiting values are shown on Figure 2(a)-(d).

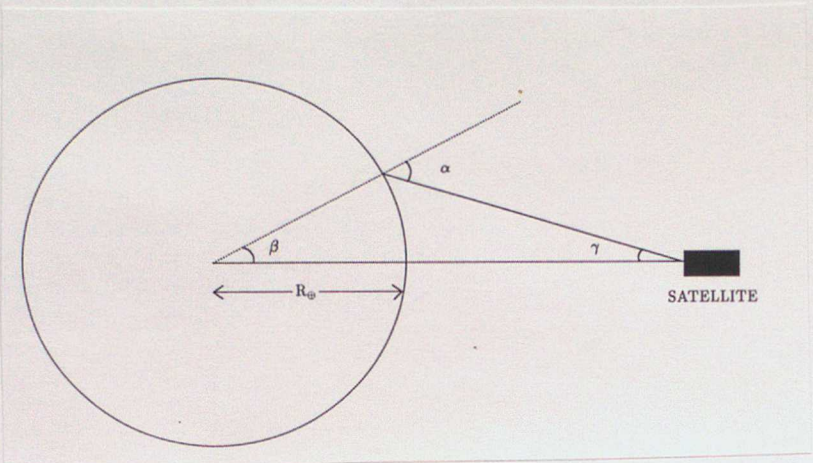
On the basis of the obliquities being equivalent at around latitude 45°, the use of polar orbiter imagery for cloud-motion wind vector determination should be pursued further. In addition, for future polar orbiters (e.g. EPS) there is a requirement for the image scanning to extend further towards the horizon. Clearly, if very large values of α are considered, there will be excessive navigation problems, associated with the fact that any uncertainty in the height of the target cloud system will give rise to large uncertainty in the horizontal position (thanks to Richard Allam for pointing this out). In deciding the maximum useful value of α, it is assumed that the navigation error must not be so large that the resulting error in the wind is greater than the error resulting from the height attribution uncertainty.

The error stemming from the height attribution uncertainty is $\Delta h \partial V/\partial z$, where Δh is the height attribution error and $\partial V/\partial z$ is the vertical wind shear. The error stemming from the navigation error is $(\Delta h \tan\alpha)/\Delta t$ where Δt is the time between succesive images used for the wind determination.

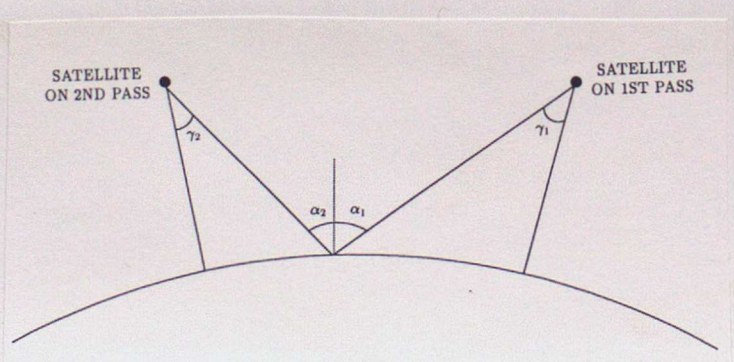
From the above it follows that the limiting value of α is given by:

$$\tan\alpha = \frac{\partial V}{\partial z}\Delta t$$

For midlatitudes an annual mean value of $\partial V/\partial z$ is $0.25 \times 10^{-2}\mathrm{s}^{-1}$, and for a polar orbiter Δt is 6×10^3s, so the limiting value of α is 86°. This corresponds to a value of 62° for γ for a satellite at a height of 825km. Thus, in conclusion it is recommended that the limiting value of the satellite viewing angle γ is increased from 55° to 62°.

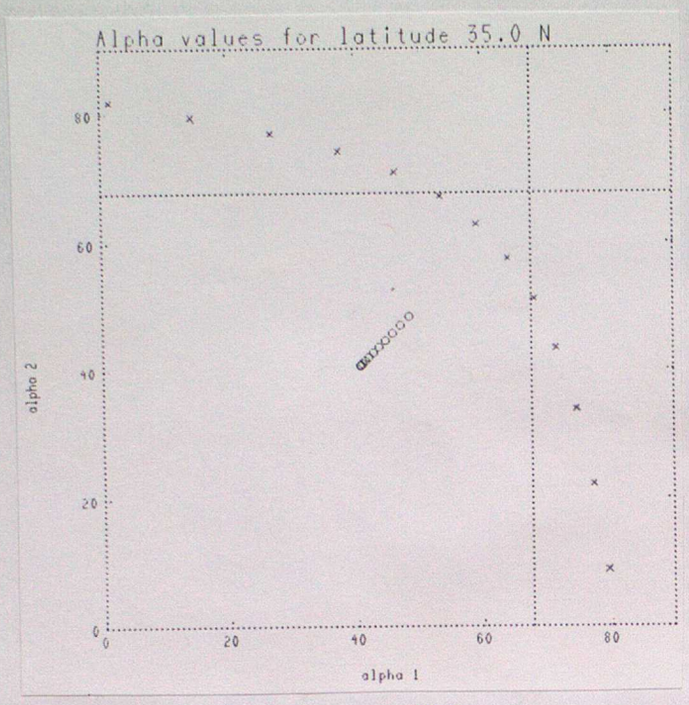


(a) geostationary satellite

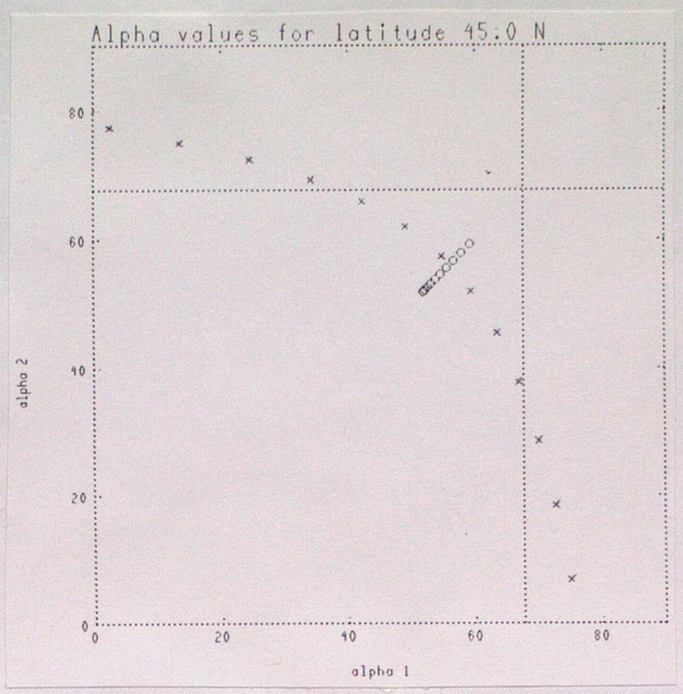


(b) polar orbiting satellite

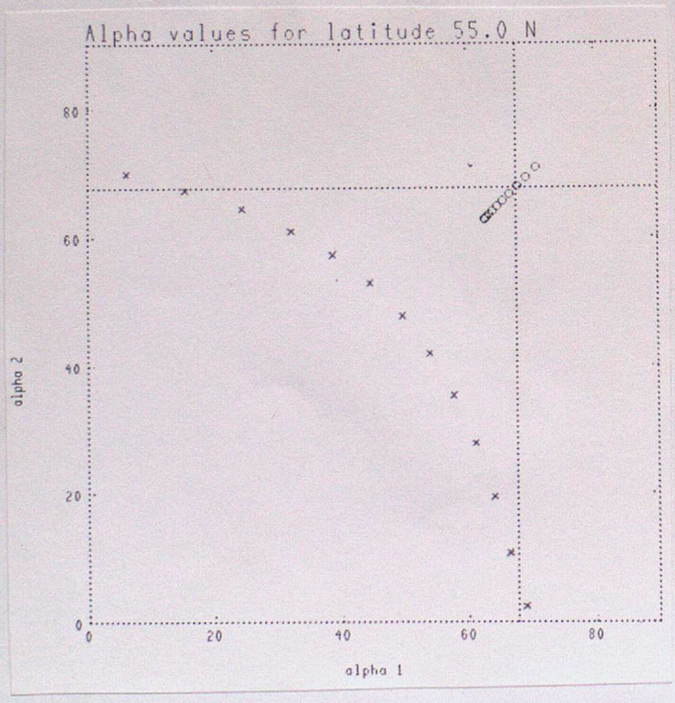
Figure 1. The obliquity angle α of a satellite



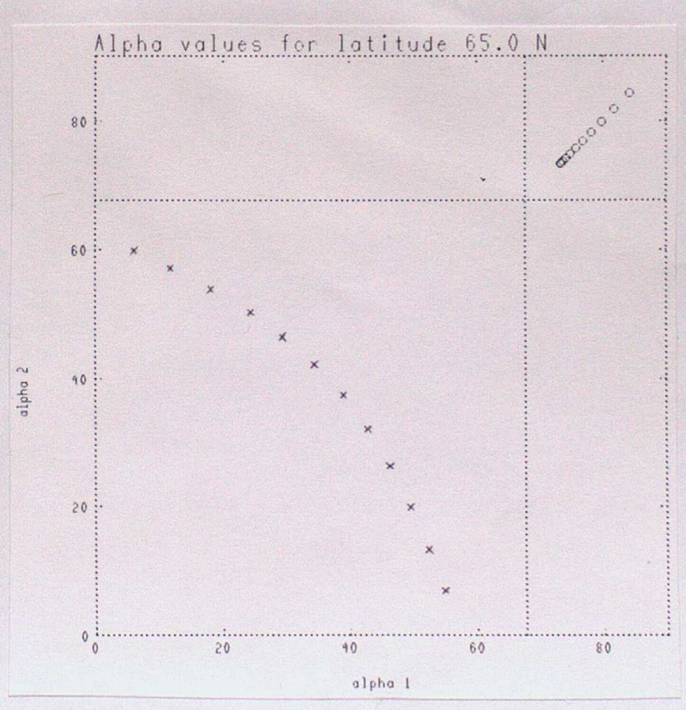
(a)



(b)



(c)



(d)

Figure 2. Plots of range of values of α for different latitudes